DEVELOPMENT OF INDIRECT VIEW SENSOR SYSTEMS: EFFECTS OF VIEWPOINT OFFSET ON HUMAN PERFORMANCE

Linda Mullins
U. S. Army Research Laboratory (ARL)
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005

ABSTRACT

Advances in sensor imaging technologies permit the Soldier to extend mission performance beyond daytime operations and into the night. Visual helmet-mounted displays (HMDs) have increasingly been used to provide supplemental information to the Soldier. When night vision sensors are used to present imagery on an HMD, the relation between the sensor and display results in a viewpoint offset, where the perceived location of objects in the environment is shifted or displaced. Configurations that use sensor offsets, on which the display screen is not aligned with the sensor, create a disparity between input from the haptic modality and the visual modality. Perceptual motor task performance becomes difficult because of this mismatch between the two modalities.

The objective of this research was to systematically investigate the effects of viewpoint offset on performance of operational tasks. Four sensor placements were tested for two tasks — walking through a mobility course and a close-in task. Time and error performance were evaluated to determine optimal sensor placement. These data were used to modify sensor placement on helmets to enhance Soldier performance.

1. INTRODUCTION

Information management and the ability to maintain situation awareness are critical elements in Soldier performance. Visual helmet-mounted displays (HMD) have increasingly been used as a means to provide improved information to the Soldier. HMD arrangements can take various forms, such as “see through,”, binocular, or monocular. While direct line of sight provides optimal viewing, this may not be feasible due to design constraints or mission requirements. The HMD design often precludes the direct view of objects with the aided eye. A display is produced by forming an image, usually from a computer or sensor, on the HMD screen. This may result in a viewpoint offset, where the perceived location of objects in the environment are shifted or displaced. Configurations using sensor offsets create a disparity between input from the haptic modality and the visual modality. Due to this mismatch between the two modalities, perceptual motor task performance becomes difficult (Redding, Rossetti, and Wallace, 2005). In an evaluation of digitally enhanced night vision goggles, the U.S. Army Research Laboratory (ARL) found that prototype goggles with a sensor offset create degradation in performance of close-in tasks (within 2 meters). In navigation tasks, Soldiers who experienced incidents of disorientation and problems navigating through the environment often walked into objects (Redden et al., 2005).

This project was funded in part by the U.S. Army Night Vision and Electronic Sensors Directorate (NVESD).

2. OBJECTIVE

Research concerning the effect of viewpoint offsets on operational performance is limited. The objective of this research is to systematically investigate the effects of viewpoint offset on performance of operational tasks. Two tasks, walking through a mobility course and a close-in task, were used to evaluate performance for four sensor locations.

3. METHOD

3.1 Participants

The civilian test participants were between the ages of 18 and 35. Their vision was tested using an OPTEC® 5000 vision tester. All participants were required to have 20/30 or better visual acuity (corrected or uncorrected) and normal stereoscopic vision to participate. Seventeen participants, 10 males and 7 females, with a mean age of 24.41 years participated in the mobility course task.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **DEC 2008**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Development Of Indirect View Sensor Systems: Effects Of Viewpoint Offset On Human Performance**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U. S. Army Research Laboratory (ARL) Human Research and Engineering Directorate Aberdeen Proving Ground, MD 21005**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002187. Proceedings of the Army Science Conference (26th) Held in Orlando, Florida on 1-4 December 2008, The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Twenty-three participants, 11 males and 12 females, with a mean age of 24.39 years participated in the close-in task.

3.2 Conditions

The NVESD provided head-mounted devices designed to study an assortment of viewpoint offsets. A Sony day camera, 40-degree field of view sensor, and a Kopin, 24.6-mm diagonal, monochromatic display were mounted on the helmet. Four sensor locations (Figure 1) were tested: centered above the eyes, directly in front of the HMD, vertically above the HMD, and directly in front of the HMD but shifted forward 17.8 cm along the z-axis (front forward). A patch was worn over the eye without the display. This prevented binocular rivalry, where the two images from each eye “fuse” into one image.

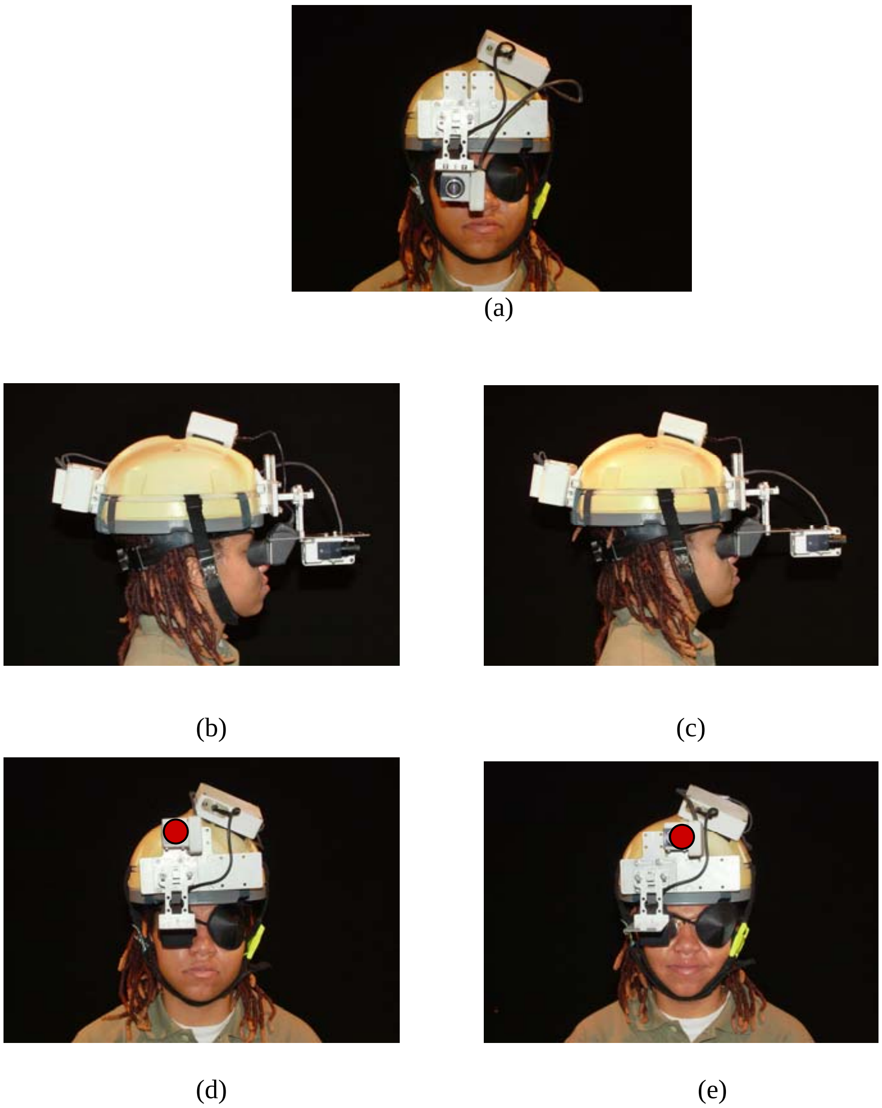

Figure 1. Sensor locations: (a) front – sensor directly in front of eye, in line with the display, front view; (b) front – sensor directly in front of eye, side view; (c) front forward – sensor in front of eye, directly in line with the display and moved forward, side view (note the increased distance between the display and sensor); (d) above – sensor above the eye in vertical alignment with the display (vertical offset); (e) center – sensor above the display and centered above the eyes (vertical and horizontal offset). A red dot has been placed over the camera on some pictures to demonstrate sensor location.

Testing started with a binocular baseline (BBL). For this baseline condition, participants performed the task under normal lighting conditions without the offset apparatus. For the second condition, monocular baseline (MBL), the participant wore an eye patch over the nonpreferred eye. After the baseline conditions, the participant donned the viewpoint offset apparatus and the display was placed over his or her preferred eye. The four viewpoint offset conditions were counterbalanced across tasks. The final condition for each task was a recovery (REC) condition. Participants removed the viewpoint offset apparatus and carried out the task under normal lighting conditions. This was a replication of the initial binocular baseline condition.

3.3 Tasks

The seven conditions were repeated for each of two tasks. After each sensor session, the participants completed an evaluation questionnaire to rate and compare the four offset conditions. Once all four sensor conditions were completed for the two tasks, participants completed the questionnaire by ranking the four sensor locations, with 1 being the most preferred.

3.3.1 Mobility Task

Visual perception plays a crucial role in navigation. Optic flow patterns, the visual pattern of motion flow as we move through the environment, provide important cues that are critical in determining direction as the individual navigates (Wood, Harvey, Young, Beedie, & Wilson, 2000). Sensor placement may create viewpoint offsets that distort the optic flow pattern. An indoor mobility course was designed to test maneuverability (Figure 2). Obstacles included furniture, windows, doorways, steps, and a ramp. To maneuver through the course, participants proceeded down a hallway, opened a door, turned right, opened a door into a room, maneuvered around furniture to open a drawer in a desk, removed an item from the drawer, placed it on the desk, climbed through a window to exit the room, followed a marked pathway (participants were instructed to step inside painted outlines marking the pathway), walked up steps, and down a ramp. A stopwatch was used to time how long it took for the participant to complete the course. The participant was videotaped as he or she traversed the course. This video was later reviewed and errors such as stumbles, reaching, etc. were evaluated. These time and error measures were used as dependent measures to evaluate performance.

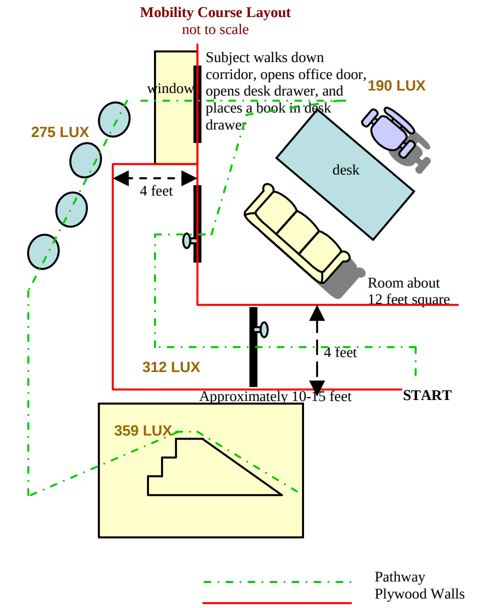

Figure 2. Layout of the mobility course. Participants walked along the green dotted pathway.

3.3.2 Rapid Sequential Positioning (RSP) Task

Helmet configurations using sensor offsets create a disparity between input from the haptic modality and the visual modality that affects eye-hand coordination, negatively impacting performance for close-in tasks (within 2 meters) (Redden et al., 2005). The RSP task was developed to quantify the benefits of video display features for teleoperator tasks in a 3-D environment (Merritt, Cole, and Ikehara, 1991). In the original study, operators manipulated a wand through a wire mesh maze to touch randomly illuminated bulbs. For this study, the RSP task was slightly modified to evaluate the effect of viewpoint offset for close-in tasks. This task required eye-hand coordination and examined operator performance for close-in tasks.

The RSP task consisted of 16 target light posts of random heights within a 20-inch-diameter circle (Figure 3). Lights mounted on top of the posts illuminated in a random fashion and the participant's task was to touch the illuminated light source as quickly as possible. Participants wore a metal fingertip. The light did not go out until he or she touched the correct light source. Latency (the time from the light turning on until the participant touched the correct light) was the dependent measure.

Figure 3. Rapid sequential positioning, front view.

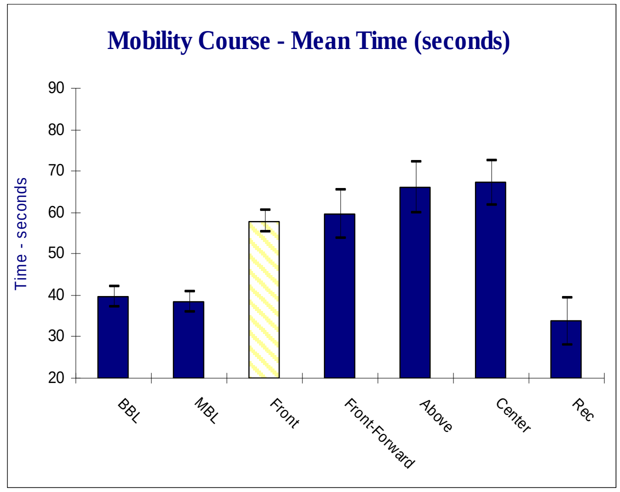

Figure 4. Mobility course time, means and standard error of the mean.

4. RESULTS AND DISCUSSION

4.3.1 Mobility Task

Means and standard deviations for each condition are displayed in Figures 4 and 5. One objective of this research was to collect data that approximated changes in performance associated with each sensor location. It was expected that the sensor located directly in front of the display, without a vertical or horizontal offset, would result in better performance relative to the other three sensor positions. For this reason the sensor position directly in front of the display was used as a reference to evaluate differences in performance. Compared to the front position, the time required to complete the course took 2.9%, 14.2%, and 16.1% longer for the front forward, above, and center positions, respectively.   Participants made 14.3% and 19.9% more errors for the above and center positions, respectively. Results indicate that errors decreased by 21.6% for the front forward position when compared to the front position.

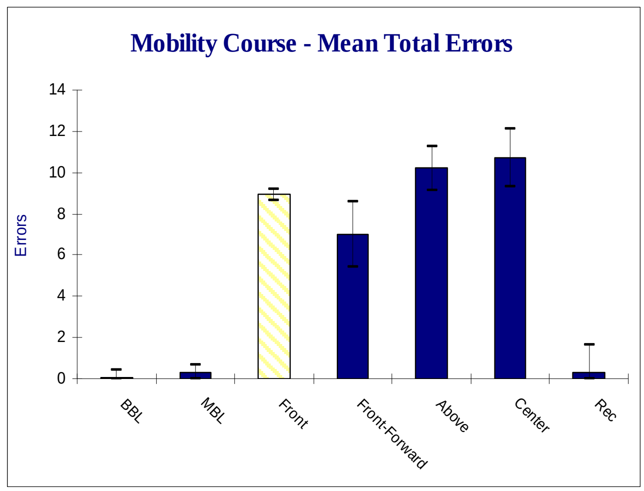

Figure 5. Mobility course errors, means and standard error of the mean.

A mixed-model analysis and pairwise comparisons were computed for time and error data. The vertical offset (above and center positions) required significantly more time to complete the course when compared to the front and front forward sensor positions. Pairwise comparisons of the total errors indicated that errors were significantly lower for the front forward position when compared to the center and above positions.

4.3.2 Rapid Sequential Positioning (RSP) Task

Means and standard deviations for each condition are displayed in Figure 6. Compared to the front position, participants took 8.3%, 22.8%, and 34.2% more time to complete the task for the front forward, above, and center positions, respectively. Results from the mixed-model analysis and pairwise comparisons followed the pattern of the mobility course time results. Latency was significantly longer for the vertical offset above and center sensor positions when compared to the front and front forward positions.

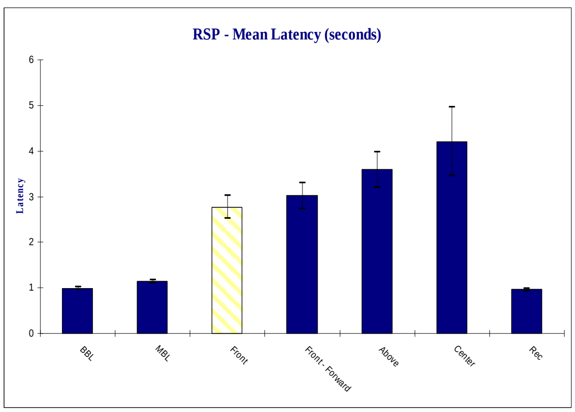

Figure 6. Rapid sequential positioning task, mean and standard error of mean for latency.

4.3.3 Participant Evaluation Questionnaires

Following each sensor session, participants completed an evaluation questionnaire that rated that sensor location for difficulty, comfort, visibility, and eye-hand coordination. A scale of 1–9 was used with 1 corresponding to “good” and 9 corresponding to “poor”. After all four sensor locations were completed, participants ranked their preferences, with 1 being the most preferred. Means and standard deviations for the participant evaluation questionnaire are in Table 1. With the exception of “discomfort” for the above condition, the sensor locations with a vertical offset (above and center) were rated lower than the sensor locations (front and front forward) that were in alignment with the display.

Participant’s ranking of preferred sensor locations are in Table 2. The front sensor position was ranked as the most preferred by the majority of the participants in each task. The front forward was ranked as the second most preferred location. The above location, with a vertical offset, was ranked third by the majority of participants. The center location, with a vertical and horizontal offset, was ranked as the least preferred by the majority of participants.

Table 1. Participant Evaluation Questionnaire Summary

Sensor Location	Difficulty	Discomfort	Visibility	Eye-Hand
Mobility Task				
Front	3.59 (2.30)	2.24 (1.75)	3.35 (2.09)	3.47 (2.12)
Front-Forward	3.88 (2.15)	2.47 (1.88)	3.35 (1.77)	4.00 (2.18)
Above	5.06 (2.00)	2.24 (1.20)	4.35 (2.26)	5.06 (2.44)
Center	5.35 (2.67)	2.82 (2.10)	4.00 (2.65)	5.53 (3.11)
RSP Task				
Front	4.13 (2.30)	2.74 (1.91)	4.70 (2.16)	4.26 (2.24)
Front-Forward	4.26 (2.22)	3.04 (2.08)	4.13 (2.28)	4.43 (2.47)
Above	5.26 (2.12)	3.13 (2.30)	4.96 (2.36)	5.78 (2.22)
Center	5.48 (2.39)	2.96 (1.97)	5.26 (2.24)	6.13 (2.28)

Mean (Standard Deviation)

Table 2. Participant Evaluation Questionnaire — Rank-Ordered Preferences

Rank	1	2	3	4
Mobility Task				
Front	11 (64.7%)	2 (11.8%)	4 (23.5%)	0 (0%)
Front-Forward	2 (11.8%)	11 (64.7%)	2 (11.8%)	2 (11.8%)
Above	2 (11.8%)	1 (5.9%)	9 (52.9%)	5 (29.4%)
Center	2 (11.8%)	3 (17.6%)	2 (11.8%)	10 (58.8%)
RSP Task				
Front	11 (47.8%)	5 (21.7%)	3 (13.0%)	4 (17.4%)
Front-Forward	7 (30.4%)	11 (47.8%)	3 (13.0%)	2 (8.7%)
Above	0 (0%)	4 (17.4%)	12 (52.2%)	7 (30.4%)
Center	5 (21.7%)	3 (13.0%)	5 (21.7%)	10 (43.5%)

Number of participants to assign that corresponding rank (percent), 1equals most preferred

5. CONCLUSIONS

The sensor and HMD setup used in this study created a viewpoint offset that distorted the individual's perception of self-reference. Performance consistently declined more for the two sensor locations with a vertical offset (above and center) than for the two sensor locations that were in alignment with the display (front and front forward). The combination of the vertical and horizontal offset associated with the center position resulted in the lowest performance measures. With the center position, the retinal image shifted so that objects in the environment that appeared to be straight ahead were actually positioned to one side of the participant, thus, contributing to declines in performance.

Participants completed the mobility course and RSP tasks more quickly when the sensor was placed directly in front of the display. Participants made fewer errors on the mobility course when the sensor was placed in front of the display and moved forward. More participants ranked the front location as their first preference. Task difficulty and eye-hand coordination were also rated as better for this sensor position.

The center sensor position resulted in the longest times for completing the mobility course and RSP tasks. More participants ranked this position as the one he or she preferred least. Task difficulty and eye-hand coordination were rated as more difficult for the center sensor position.

The objective of this research was to evaluate and quantify the effects of sensor placement on individual performance. Objective performance measures indicate that placing the sensor in front of the display (when possible from a design standpoint) is preferable. Participants completed the tasks more quickly and with fewer errors when the sensor was situated in front of the display.

REFERENCES

Merritt, J.O., Cole, R.E., and Ikehara, C. (1991). *A Rapid-Sequential-Positioning Task for Evaluating Motion Parallax and Stereoscopic 3D Cues in Teleoperator Displays.* Presented at the 1991 IEEE Conference on Systems, Man, and Cybernetics, October 13–16 at the University of Virginia, Charlottesville.

Redden, E.S., Bonnett, C.C., Carstens, C.B., Heller, F., Holloway, C., Parker, C., Pettitt, R., and Turner, D. (2005). *Digital enhanced night vision goggles limited user evaluation.* (Tech. Rep. ARL-TR-3536). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Redding, G.M., Rossetti, Y., and Wallace, B. (2005). Applications of prism adaptation: A tutorial in theory and method. *Neuroscience and Biobehavioral Reviews, 29,* 431–444

Wood, R.M., Harvey, M.A., Young, C.E., Beedie, A., and Wilson, T. (2000). Weighting to go with the flow. *Current Biology, 10,* R454–R546.